An Assessment of the Potential for Reducing Future Combat Deaths through Medical Technologies and Training

Christopher G. Blood, JD, MA, Juan Carlos Puyana, MD, Paul J. Pitlyk, MD, David B. Hoyt, MD, H. Scott Bjerke, MD, Julia Fridman, BA, G. Jay Walker, BA, James M. Zouris, BS, and J. Zhang, MSc, MA

Background: **We examined clinical records of combat casualties that died subsequent to reaching a medical treatment facility in an effort to determine whether new medical technologies or enhanced training might contribute to a reduction in combat deaths.**

Methods: **Hospital records of 210 fatal combat casualties were independently reviewed by four surgeons. The surgeons assessed each fatality to determine whether it would be preventable if the trauma were sustained today and treated with currently available technology and training.**

Results: **In 8% of the cases, the four surgeons independently agreed that the deaths would be possibly preventable if the same traumas were incurred today. In an additional 17% of the cases, three of the four surgeons judged the deaths to be possibly preventable today. Causes of death viewed as most likely to be salvageable today included hemorrhage, severe burns, pulmonary edema, and sepsis. The medical technologies most often mentioned to have a potentially lifesaving effect were ventilators/respirators, computed tomographic scanners, ultrasound, and antibiotics. Areas of training most often mentioned to have a potential impact on the salvageability of the trauma cases reviewed were damage control, ventilator management, liver packing, respiratory distress management, and burn management.**

Conclusion: **Surgeons reviewing records of past combat deaths indicated that reductions in the incidence of combat deaths through deployment of improved medical technologies and training is possible. Deployment of the noted technologies and proficiency in the cited training has the potential for reducing deaths by 8% to 25% when compared with the died-in-hospital incidence among casualties in the last sustained conflict.**

Key Words: **Combat traumas, Died of wounds, Killed in action, Wounded in action, Preventable deaths.**

J Trauma. 2002;53:1160–1165.

In the aftermath of combat operations in which casualties are sustained, questions often arise as to whether some deaths might have been prevented had certain medical technologies been deployed or specific medical training been implemented. However, even where the deployment of certain medical equipment or training could conceivably make a lifesaving difference, it is important to note that immediate access to the wounded on the battlefield is often constrained by the operational environment. Examples of such constraints would include ongoing hostilities that prevent medical personnel from reaching the wounded individual and even the absence of knowledge that an individual has been wounded. Also important to any discussion of potentially "preventable" combat deaths is the terminology used to refer to different casualties. A serviceman who dies from his injuries before reaching a medical treatment facility is typically termed a KIA (killed in action); those individuals who die after reaching a treatment facility are most often categorized as a DIH (died in hospital) or as a DOW (died of wounds).[1]

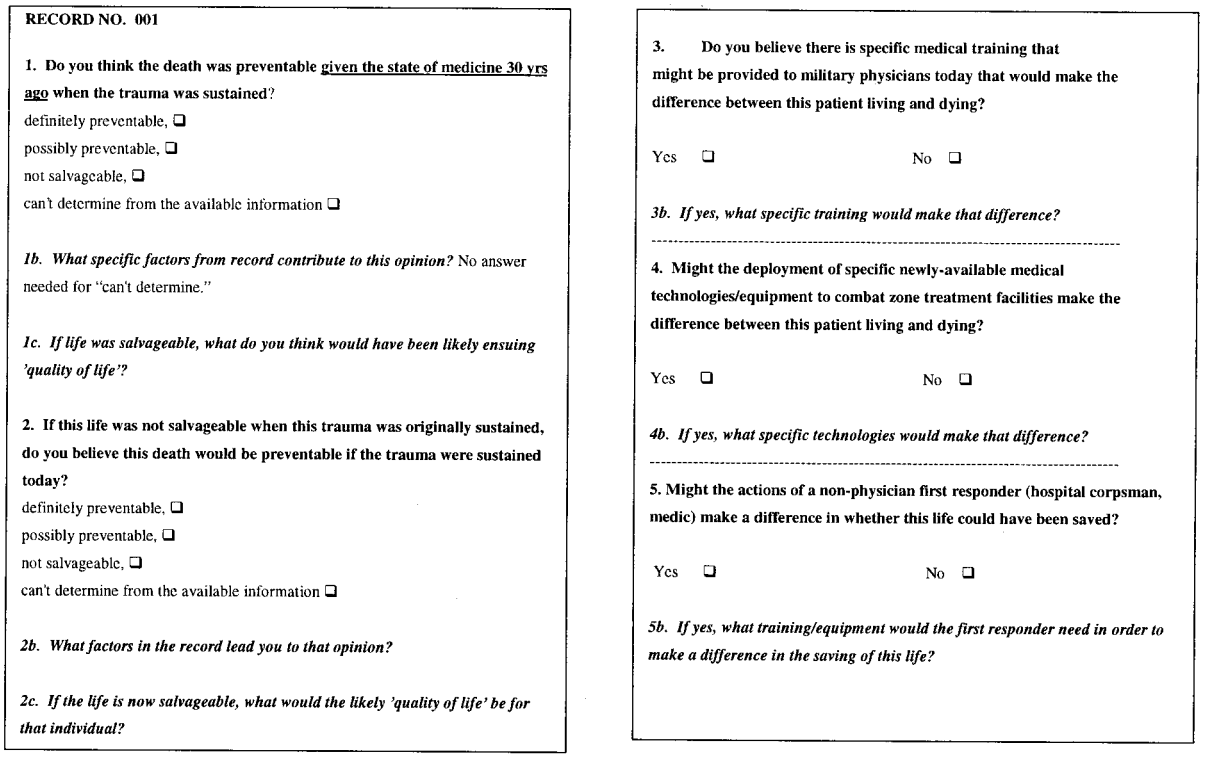
Although combat deaths might potentially be reduced through nonmedical interventions such as changes in battle tactics or advances in body armor, the focus of the present investigation is on the care received after the wounded soldier reaches a treatment facility. The notion that some hospital deaths may be preventable is not a new one.[2] A 1985 review by Cales and Trunkey listed no fewer than 29 preventable trauma death studies.[3] One study, conducted at hospitals affiliated with the New York Medical College, classified 11.9% of the trauma deaths as preventable.[4] A study of fatal traumas in Dublin categorized 9 of 28 deaths (32%) after hospital admission as potentially preventable.[5] Another study examining trauma deaths in Denver judged 3% of the deaths to be potentially preventable and another 2% to be frankly preventable.[6]

The trauma studies noted above have used panels of surgeons to evaluate whether the deaths were preventable. The ratings by the surgeons are typically derived from review of predeath clinical records, autopsy records, or both. Approaches vary in these studies with regard to whether a preventable death requires unanimous agreement of the ex-

Submitted for publication December 4, 2001.
Accepted for publication June 9, 2002.

From the Naval Health Research Center (C.G.B., J.M.Z.), Division of Trauma, University of California, San Diego Medical Center (D.B.H.), San Diego, Santa Clara Valley Medical Center, Department of Neurological Surgery, University of California, San Francisco (P.J.P.), San Francisco, California, Surgical Intensive Care Unit, University of Pittsburgh Medical Center (J.C.P.), Pittsburgh, Pennsylvania, Trauma Services, Methodist Hospital (H.S.B.), Indianapolis, Indiana, and Geo-Centers, Inc. (J.F., G.J.W., J.Z.), Rockville, Maryland.
Technical Report No. 01-28 supported by the Office of Naval Research, Arlington, Virginia, Department of the Navy, under Work Unit No. 62233N.M3P30.001-60105.
The views expressed in this article are those of the authors and do not reflect the official policy or position of the U.S. Navy, the Department of Defense, or the U.S. Government.
Address for reprints: Christopher G. Blood, JD, MA, Naval Health Research Center, P.O. Box 85122, San Diego, CA 92186-5122.

DOI: 10.1097/01.TA.0000028856.22514.C1



RECORD NO. 001

1. Do you think the death was preventable given the state of medicine 30 yrs ago when the trauma was sustained?
definitely preventable, ❑
possibly preventable, ❑
not salvageable, ❑
can't determine from the available information ❑

1b. What specific factors from record contribute to this opinion? No answer needed for "can't determine."

1c. If life was salvageable, what do you think would have been likely ensuing 'quality of life'?

2. If this life was not salvageable when this trauma was originally sustained, do you believe this death would be preventable if the trauma were sustained today?
definitely preventable, ❑
possibly preventable, ❑
not salvageable, ❑
can't determine from the available information ❑

2b. What factors in the record lead you to that opinion?

2c. If the life is now salvageable, what would the likely 'quality of life' be for that individual?

3. Do you believe there is specific medical training that might be provided to military physicians today that would make the difference between this patient living and dying?

Yes ❑ No ❑

3b. If yes, what specific training would make that difference?

---

4. Might the deployment of specific newly-available medical technologies/equipment to combat zone treatment facilities make the difference between this patient living and dying?

Yes ❑ No ❑

4b. If yes, what specific technologies would make that difference?

---

5. Might the actions of a non-physician first responder (hospital corpsman, medic) make a difference in whether this life could have been saved?

Yes ❑ No ❑

5b. If yes, what training/equipment would the first responder need in order to make a difference in the saving of this life?

Fig. 1. *Reducing combat deaths questionnaire.*

perts or whether a simple majority of the panel is sufficient. Interrater reliability of preventable death judgments has, in the past, generally been low.[7]

That some trauma deaths within state-of-the-art hospitals are being deemed preventable leaves open the possibility that some trauma deaths treated in less sophisticated medical facilities in combat zones might likewise be preventable. The present study examines clinical records of combat casualties that died after reaching a hospital. The objective of this investigation is to identify medical technologies and training that might reduce such casualties in future combat deployments by an assessment of the potential preventability of past combat deaths if the traumas were sustained today.

MATERIALS AND METHODS

Nine hundred sixty U.S. Marines serving in Vietnam who died of combat wounds after reaching a hospital were identified using an inpatient database maintained at the Naval Health Research Center.[8] Diagnoses, dates of admission, hospitals, and service numbers of these casualties were then extracted from the inpatient database. A random sample of 300 clinical records corresponding to these admissions was requested from the National Personnel Records Center in St. Louis, Missouri. Because some clinical accounts are either never fully documented or are subsequently lost in the transfer of records from a combat zone, a total of 210 records of DIH combat traumas were available for this analysis. No systematic differences were found between the diagnosis codes in the inpatient database of the records that were available and those that were unavailable; that is, the types of wounds were similar. Moreover, post hoc sample size analysis[9] indicated the sample to be representative of the overall population of DIHs at a 95% confidence level with a 0.06 margin of error.

The clinical records obtained from the National Personnel Records Center varied as to the degree of documentation contained therein. Some records had extensive nurse's notes, doctor's notes, treatment details, and autopsy documentation. Other records, especially those of casualties who died shortly after arriving at a treatment facility, were considerably more abbreviated. Before the records were given to the surgeons for review, all information identifying the patient, next of kin, and medical personnel who treated the individual was expunged. Four surgeons with extensive trauma experience (J.C.P., P.J.P., D.B.H., H.S.B.) reviewed the clinical records. The surgeons did not know who their fellow reviewers were, nor were there any communications among the surgeons. A separate questionnaire for each of the 210 trauma cases was provided to each surgeon (Fig. 1). This research was conducted in compliance with all applicable federal regulations governing the protection of human subjects in research.

RESULTS

Causes of Death, Wounding Agents, and Temporal Circumstances

The most commonly recorded causes for these combat deaths, as shown in Table 1, were intracranial injuries and

Table 1 Causes of Death among Combat Trauma Cases Dying in Hospitals

Cause of Death	No.	%
General intracranial injury	68	32.4
Hemorrhage and coagulopathy	39	18.6
Cerebral hemorrhage, edema, or hematoma	24	11.4
Multiple organ complications	13	6.2
Brain stem injury	12	5.7
Severe burns	11	5.2
Sepsis	8	3.8
Pulmonary edema	6	2.9
Acute respiratory distress syndrome (ARDS)	2	1.0
Atelectasis	2	1.0
Flail chest	2	1.0
Hemopneumothorax	2	1.0
Hemothorax	2	1.0
Laceration to major blood vessels	2	1.0
Spinal cord injury	2	1.0
Bronchopneumonia	1	0.5
Cardiovascular collapse	1	0.5
Cerebral anoxia	1	0.5
Encephalopathy	1	0.5
Fat embolus syndrome	1	0.5
Hepatic trauma	1	0.5
Lung contusion	1	0.5
Lung tissue destruction	1	0.5
Iatrogenic event involving anesthesia	1	0.5
Meningitis	1	0.5
Pneumothorax	1	0.5
Pulmonary hematoma	1	0.5
Pulmonary hemorrhage	1	0.5
Pulmonary insufficiency	1	0.5
Pulmonary obstruction	1	0.5

hemorrhage/coagulopathy. The wounding agents are listed in Table 2. Three fourths of the trauma admissions were recorded as resulting from gunshot wounds and explosive devices. Fig. 2 demonstrates the lengths of time between hospital admission and death among the combat trauma cases; time of admission was known for 186 of the 210 cases. As can be seen in this figure, almost 19% of the deaths occurred within 2 hours of admission, and 59% of the deaths occurred within the first 12 hours.

Table 2 Wounding Agents among Combat Trauma Patients Dying in Medical Treatment Facilities

Weapon	Count	%
Gunshot	107	51.0
Explosive device	58	27.6
Booby trap	10	4.8
Mine	10	4.8
Mortar	9	4.3
Shrapnel	3	1.4
Artillery	2	1.0
Gasoline fire	2	1.0
Grenade	2	1.0
Mine/fire	2	1.0
Downed helicopter	2	1.0
Blast	1	0.5
Booby trap/fire	1	0.5
Howitzer	1	0.5

Time of injury was recorded on 109 records. In 55% of these cases, the time from injury to admission was 1 hour or less; in 23% of these traumas, admission was between 1 and 2 hours after injury; and in another 10% of these cases, admission was within 3 hours. Most records gave no indication as to what, if any, treatment was provided before arrival at the hospital.

Two hundred four of the trauma cases died at fixed or shipboard treatment facilities in the combat zone; three cases died at a facility in Japan; and three cases were transferred to the continental United States before death occurred. One hundred eighty-nine of the 210 casualties died at the initial treatment facility; 19 cases were transferred to a second facility before death occurred; and there was a single case each where there were transfers to a third and fourth facility before death occurred.

Preventability Analyses

The percentage of trauma deaths judged "definitely preventable" today by the four individual surgeons ranged from 1.0% to 11.0%, with a mean of 5.4%. The percentage of DIHs viewed as "possibly preventable" today varied from 26.2% to 41.9% and averaged 34.9%. Table 3 lists the percentages corresponding to the preventable/unsalvageable responses of the four surgeons to the 210 trauma cases reviewed.

There was appreciable agreement among the trauma surgeons participating in this study as to whether specific trauma deaths, if seen today, would be preventable. Table 4 indicates that at least three of the four surgeons were in agreement regarding the preventability of death in 159 of the 210 trauma cases. In addition, there were another 16 cases where at least three surgeons indicated that the deaths were definitely or possibly preventable today (e.g., two said definitely preventable and one said possibly preventable). A traditional measure of interrater reliability, the kappa statistic,[10] yielded a value of 0.32 when the level of agreement among the surgeons was analyzed. Kappa statistics between 0.41 and 0.60 indicate moderate agreement, those between 0.21 and 0.40 reflect fair agreement, and those below 0.20 represent negligible agreement beyond chance.[7]

Table 4 may be contrasted with Table 5, which indicates that there was not unanimous agreement that any of the trauma deaths were, at the time that they were sustained, definitely preventable or even possibly preventable. Furthermore, there was only one trauma in which three surgeons judged the death to be definitely preventable at the time it occurred and only 11 traumas in which three surgeons judged the death to be possibly preventable at time of sustainment.

Unsalvageable Then but Possibly Preventable Today

There were 26 trauma cases where three or more surgeons thought the life was unsalvageable 30 years ago but where the death was judged by at least three surgeons to be

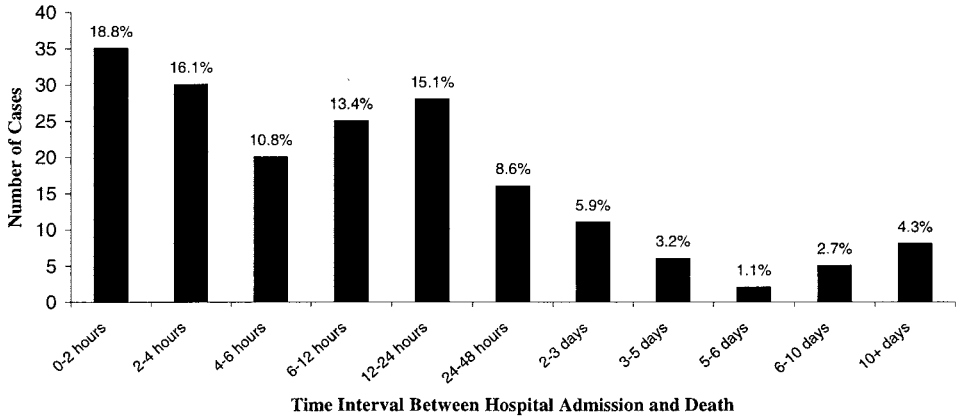


Fig. 2. *Time interval between hospital admission and death among combat trauma patients dying in medical treatment facilities.*

definitely/possibly preventable if the same trauma presented at a combat hospital today. Examination of these cases may provide some insights into the types of traumas that may be most likely to benefit from the deployment of new medical technologies or enhanced training regimens. Table 6 lists the causes of death among those traumas deemed unsalvageable when they occurred but possibly salvageable today.

Table 7 presents the types of technology/equipment that the surgeons indicated might make a lifesaving difference among the 26 trauma cases that were viewed to be salvageable today but not when they occurred. It can be seen from this table that the technologies most mentioned as having a potential lifesaving effect were modern ventilators/respirators and computed tomographic scanners.

Table 8 similarly lists the training that the surgeons judged would be most likely to have a potential lifesaving impact, on the basis of the 26 combat traumas that were judged to be salvageable today but not when they occurred 30 years ago. Leading this list were proficiency in damage control, ventilator management, liver packing, and respiratory distress management.

In 10 of the 26 trauma cases judged "now salvageable," three or more surgeons thought the ensuing quality of life would be good or normal. In 4 of the 26 cases, the quality of

Table 3 Responses of Trauma Surgeons Reviewing Clinical Records of Combat Traumas as to Whether Such Deaths Would Be Preventable if Injuries Were Sustained Today

	Surgeon 1 (%)	Surgeon 2 (%)	Surgeon 3 (%)	Surgeon 4 (%)	Average (%)
Definitely preventable	6.7	2.9	11.0	1.0	5.4
Possibly preventable	39.5	31.9	26.2	41.9	34.9
Not salvageable	51.9	63.8	55.7	49.0	55.1
Can't determine	1.9	1.4	7.1	8.1	4.6

Table 4 Number of Trauma Cases in Which at Least Three of the Four Surgeons Agreed as to Salvageability if the Trauma Were Sustained Today

	Definitely Preventable	Possibly Preventable	Unsalvageable	Can't Determine	Total
All four surgeons	0	17	59	0	76
Three surgeons	1	36	46	0	83
Total	1	53	105	0	159

Table 5 Number of Traumas with Unanimity/Near-Unanimity of Agreement as to Salvageability Given Technologies Available at Time the Injury Was Sustained

	Definitely Preventable	Possibly Preventable	Unsalvageable	Can't Determine	Total
All four surgeons	0	0	105	0	105
Three surgeons	1	11	49	3	64
Total	1	11	154	3	169

Table 6 Traumas Judged Originally Unsalvageable but Salvageable Today

Cause of Death	No.	%
Hemorrhage and coagulopathy	8	30.8
Severe burns	3	11.5
Atelectasis	2	7.7
Pulmonary edema	2	7.7
Sepsis	2	7.7
ARDS	1	3.8
Brain stem injury	1	3.8
Bronchopneumonia	1	3.8
Cerebral hemorrhage, edema, or hematoma	1	3.8
Fat embolus syndrome	1	3.8
Hemopneumothorax	1	3.8
Hepatic trauma	1	3.8
Laceration to major blood vessels	1	3.8
Lung contusion	1	3.8

ARDS, acute respiratory distress syndrome.

life was expected to be poor; and in the remaining 12 cases, there was no general agreement among the surgeons regarding the ensuing quality of life.

Types of Deaths with Most and Least Preventability Potential

There were 17 trauma cases in which all four surgeons independently indicated that, were the traumas sustained today, the deaths would be possibly preventable; in another 36 trauma cases, three of the four surgeons independently judged the death to be possibly preventable if sustained today (Table 4). The causes of death in the 17 traumas where there was unanimity of agreement were as follows: sepsis in 5 cases; hemorrhage/coagulopathy in 4 cases; pulmonary edema in 2 cases; and cerebral edema, respiratory distress, hemopneumothorax, atelectasis, lung tissue destruction, and fat embolus syndrome in 1 case each. The causes of death among the 36 traumas where there was near-unanimity that the deaths would be possibly preventable were hemorrhage/coagulopathy in 15 cases; severe burns in 4 cases; multiple organ trauma in 3 cases; general intracranial injury and intracerebral hemorrhage in 2 cases each; and brain stem injury, encephalopathy, pulmonary insufficiency, pulmonary obstruction, pulmonary venous thrombosis, respiratory distress, flail chest, lung contusion, bronchopneumonia, and severe vascular injury in 1 case each. Table 4 also indicates that there was a single case where three surgeons independently indicated that the death was definitely preventable. The cause of death in this last instance was an iatrogenic event related to anesthesia administration.

Tables 4 and 5 also indicate substantial agreement with regard to cases that three or four surgeons independently judged to be unsalvageable. There were 105 trauma cases in which three or more surgeons rated the case as unsalvageable when it occurred and where at least three surgeons also rated it as unsalvageable if the trauma were to be sustained today. The causes of death in these 105 cases were general intracranial injury in 58 cases, cerebral hemorrhage/edema in 20 cases, brain stem injury in 10 cases, hemorrhage/coagulopathy in 7 cases, multiple organ trauma in 6 cases, and severe burns and hemopneumothorax in 2 cases each.

Table 7 Medical Technologies Indicated to Have Potential Lifesaving Effect

Technology/Equipment	No. of Mentions
Modern ventilators/respirators	23
CT scanner	10
Modern antibiotics	6
Ultrasound/Doppler ultrasound	5
Portable ICU	4
Angiography	3
Dialysis equipment	3
Hemoglobin solutions	3
Portable/flexible bronchoscope	2
Interventional radiology	2
Swan-Ganz catheter	2
Low-molecular-weight heparin	1
Cardiac echo	1
Heart bypass equipment	1
Bovie electrocautery	1
Argon beam laser	1
Oxygen saturation monitoring	1
Hemodynamic monitors	1

CT, computed tomographic; ICU, intensive care unit.

Table 8 Medical Training Cited as Having a Potential Lifesaving Effect

Recommended Area of Training	No. of Mentions
Damage control surgery	10
Ventilator management	9
Liver packing/damage control	8
Respiratory distress management	8
Burn care/modern burn management	4
Fluid resuscitation	2
Ultrasound	2
Invasive interventional radiology	2
Oxygen saturation monitoring	2
Angiography	1
Intracranial pressure control	1
Abdominal compartment syndrome	1
Management of pancreatic injuries	1
Advanced trauma life support	1
Hemodynamic monitoring	1
Deep vein thrombosis prophylaxis	1
Postoperative ICU care	1
Thoracic surgical training	1
Use of pulmonary artery catheters	1
Use of draining in pelvic/rectal trauma	1
Pulmonary CT scanning	1
Bronchoscopy	1
Hepatic exposure	1

ICU, intensive care unit; CT, computed tomographic.

Agreement on Whether Technology, Training, or First Responder Would Make a Difference

In 7 of the 210 trauma cases reviewed, there was unanimous agreement among the surgeons that deployment of

medical technologies might make a difference in whether that particular trauma would be salvageable today. In another 18 cases, 3 of the 4 doctors agreed that now-available technologies might make a lifesaving difference for a particular trauma. The kappa statistic for the level of agreement on this question was 0.158. The level of agreement as to whether training would make a lifesaving difference was slightly lower: in only 2 specific trauma cases did all four surgeons agree training would have a lifesaving difference; in another 20 trauma cases, three surgeons agreed that training might make a difference. The kappa statistic for level of agreement on this issue was 0.138. The most prevalent responses to the specific technologies and training that would prove useful are listed in Tables 7 and 8.

In response to the question of whether any actions of a "first responder" today might make a lifesaving difference with respect to the traumas reviewed, there was considerable agreement that such actions would not make a difference. Three of the surgeons thought the actions of a first responder might make a difference in an average of only 1.5% of the 210 cases. However, the fourth surgeon felt that a first responder might make a difference in almost one fourth of such cases. This fourth surgeon advocated the following activities by the first responder in various trauma cases: early field intubation, use of tourniquet and pressure dressing, and early use of antibiotics.

DISCUSSION

The present investigation sought to assess whether future combat deaths might be reduced through medical practices, and, if some deaths might be prevented, to illuminate the specific medical technologies or training that would yield such lifesaving differences. The clinical records reviewed were a randomly selected representative sample of the combat wounds that ended in death after reaching a second- or third-echelon medical treatment facility. All four surgeons who reviewed the 210 clinical records of combat traumas ending in death at treatment facilities in the Vietnam conflict believed that, if the traumas were incurred today, some deaths would be definitely preventable and others would be possibly preventable. There was unanimous agreement that 8% of the deaths would be possibly preventable if incurred today, and near-unanimity that another 17% of the deaths would be possibly preventable. It is noted that often in "preventability of death" studies, the surgeons reviewing the clinical records form a working panel where attempts are made by individual surgeons to persuade fellow panelists of the "correctness" of his or her judgment. A major strength of this study is that, because the surgeons did not communicate, where there was agreement, that agreement was independently achieved. Furthermore, as measured by the kappa statistic, there was fair agreement among the surgeons as to whether the reviewed deaths were preventable/unsalvageable.

A major focus of this study was on traumas judged to be unsalvageable when they occurred but where the deaths were deemed preventable if the same traumas were incurred today. That there was near-unanimity that a life could not be salvaged 30 years ago, and then near-unanimity that the same death might be preventable today, suggests that for these 26 trauma cases there have been advances in medical practices that would potentially have a lifesaving impact. The fatalities most commonly viewed as preventable today were traumas where the cause of death was hemorrhage, severe burns, pulmonary edema, and sepsis.

The judgments of the surgeons reviewing the records of this study indicate that reductions in the incidence of combat deaths through improved medical technologies and training are possible. Individually, all four surgeons thought that many traumas would benefit from the deployment of specific technologies and enhanced proficiency through specific training. There was agreement among at least three of the four surgeons that technologies would have a lifesaving impact in 11% of the reviewed trauma cases. Similarly, at least three of the four surgeons thought that proficiency in certain training areas would make a difference in 10% of specific trauma cases. The medical technologies/equipment most often mentioned to have a potentially lifesaving effect were ventilators/respirators, computed tomographic scanners, ultrasound, and antibiotics. The areas of training most often mentioned to have a potentially lifesaving impact were damage control, ventilator management, liver packing, respiratory distress management, and burn management. Through the deployment of such technologies and with heightened training in these areas, it is possible that the relatively low incidence of individuals who succumb to their combat wounds after reaching a hospital could be driven even lower.

REFERENCES

1. Henderson JV. The importance of operational definitions in design of a combat casualty care system. *J Med Syst.* 1983;7:413–426.
2. Dubois RM, Brook RH. Preventable deaths: who, how often, and why? *Ann Intern Med.* 1988;109:582–589.
3. Cales RH, Trunkey DD. Preventable trauma deaths. *JAMA.* 1985; 254:1059–1063.
4. Cayten CG, Stahl WM, Agarwal N, Murphy JG. Analyses of preventable deaths by mechanism of injury among 13,500 trauma admissions. *Ann Surg.* 1991;214:510–521.
5. Caldwell MT, McGovern EM. Fatal trauma: a five-year review in a Dublin hospital. *Ir J Med Sci.* 1993;162:309–312.
6. Sauaia A, Moore FA, Moore EE, et al. Epidemiology of trauma deaths: a reassessment. *J Trauma.* 1995;38:185–193.
7. MacKenzie EJ, Steinwachs DM, Bone LR, Floccare DJ, Ramzy AI. Inter-rater reliability of preventable death judgments: the Preventable Death Study Group. *J Trauma.* 1992;33:292–303.
8. Garland FC, Helmkamp JC, Gunderson EKE, et al. *A Guide to the Computerized Medical Data Resources of the Naval Health Research Center*. San Diego, CA: Naval Health Research Center; 1987. Report No. 87-13.
9. Lenth R. Java applets for power, and sample size. Available at: http://www.stat.uiowa.edu/~rlenth/Power. Accessed November 30, 2001.
10. Fleiss JL. Measuring nominal scale agreement among many raters. *Psychol Bull.* 1971;76:378–382.